NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 3075

MEASUREMENTS OF PRESSURE AND TEMPERATURE FOR APPRAISAL OF THE TEMPERATURE METHOD OF AIRSPEED CALIBRATION IN THE LOWER STRATOSPHERE

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SUMMARY

An investigation was made to determine whether the temperature and pressure conditions in the lower stratosphere would meet the requirements of the temperature method for accurate calibration of airspeed installations. Measurements of temperature and pressure were made in flights of a swept-wing fighter airplane on four clear days in March and April 1953 over land near Langley Field, Virginia. The results indicated that, although the temperature lapse rate was favorable to the method, large and erratic variations of temperature with time and distance precluded accurate calibration. Unfavorable atmospheric conditions had also been found previously in an investigation of the upper troposphere (NACA TN 2807).

INTRODUCTION

The temperature method of airspeed calibration proposed in reference 1 is particularly attractive because of the simple instrumentation and flight program involved. For satisfactory accuracy, however, the method requires (1) a rate of change of temperature with pressure appreciably below adiabatic and (2) no large and rapid variations of temperature with time or horizontal distance that may be covered in the tests at a given pressure level.

Although a survey of the available meteorological literature indicated that satisfactory temperature lapse rates would be obtained in the upper troposphere and in the stratosphere, sufficiently detailed information on the pressure variations with time and horizontal distance did not appear to be available. A flight investigation was therefore made to obtain such information and the results are presented in reference 2. Because of the limited performance of the airplane used for the tests, the surveys of pressure and temperature were limited to the upper troposphere (an altitude range from 23,000 to 31,000 feet) and the highest speed available for a trial calibration was a Mach number of about 0.8. The results of these measurements indicated that, on days when the temperature lapse rate met the requirement of the temperature method of airspeed calibrations, the variation of temperature with time and horizontal distance at a given pressure level was unsatisfactorily large and irregular. Furthermore, on days when the variation with time and distance was satisfactory, the temperature lapse rate was adiabatic or very nearly so. These results therefore indicated very little or no promise for the use of the temperature method in the upper troposphere. The question of the suitability of the conditions in the stratosphere, however, remained.

When an airplane with a higher performance than that used in reference 2 became available, the surveys of temperature and pressure were continued into the lower stratosphere (an altitude range from 35,000 to 45,000 feet) and an airspeed calibration was made up to about sonic speed by the temperature method. The evaluation of these surveys and airspeed calibrations is presented herein.

INSTRUMENTATION

Measurements of static pressure, impact pressure, and temperature were recorded on photographic film and synchronized by a 0.1-second timer.

Static-pressure and impact-pressure recorder.- An instrument recorded static and impact pressures obtained from a pitot-static tube mounted on a boom about 2 fuselage maximum diameters ahead of the fuselage nose of the swept-wing jet-fighter airplane (fig. 1). The reading accuracy for static and impact pressure was about ± 0.2 millibar. The errors in static and impact pressures caused by lag were computed and were found to be insignificant.

Thermometer.- Two thermometers and oscillographs were used to record temperature. The adiabatic-type resistance sensing elements of both thermometers are shown mounted under the fuselage nose in figure 1. The thermometers were of the same design as that described in reference 2. The oscillographs installed in the airplane had different sensitivities. The approximate reading accuracy for one oscillograph was $\pm 0.07^{\circ}$ C and for the other oscillograph was $\pm 0.12^{\circ}$ C. The temperatures presented in this paper were evaluated from data obtained with the more sensitive oscillograph; the other thermometer was used as a check instrument. Some comparisons of data obtained in each flight with the two thermometers indicated an occasional difference of measured temperature of no more than about 0.3° C. As stated in reference 2, the recovery factor of the thermometers is about 0.99 with an uncertainty of about ± 0.01; for the altitude of these tests, the time lag is negligible (about 0.1 second).

FLIGHT PROCEDURES

The data were obtained in four flights on clear days in March and April 1953. Two surveys of the variations of atmospheric pressure and temperature were made in spiral climbs for each flight in order to establish a pressure-temperature plot to be used in the airspeed calibration of the high-speed dive. The high-speed dive was performed immediately following the first survey and preceding the second survey. About 8 minutes were required for each survey while each dive was of about 1 minute duration.

Surveys.- The variations of temperature and static pressure were measured at a Mach number of about 0.8 in spiral climbing flight. The climbs were made near the ceiling of the airplane and covered a range of altitudes from about 35,000 to 45,000 feet. The angle of bank in the climbs was limited by the climb performance of the airplane to 10°; the resulting helix was undesirably large and had a diameter of nearly 40 miles.

Dives.- The high-speed dive following the first climb survey of each flight was made straightaway toward the center of the climb helix. The dives started at an altitude of about 45,000 feet and a Mach number of about 0.8 and ended in a pullout at about 35,000 feet; a maximum Mach number of about 1.0 was obtained in the dive. The dives covered approximately 8 miles horizontal distance. As in the climb surveys, continuous records were taken of static pressure, impact pressure, and temperature.

RESULTS AND DISCUSSION

Pressure-temperature surveys.- Measurements of temperature and pressure in the surveys were converted to free-stream values by using unpublished results of a calibration (by the radar method of ref. 3) of a similar airspeed installation on another airplane of the same design. The method of correcting measured temperature and pressure to free-stream values is given in reference 2.

The variations of free-stream temperature with static pressure are shown in figure 2 for surveys in four flights. Reports of turbulence, haze, and vapor trails are also included on the plots for flights made on March 27, March 30, and April 8. Similar information was not reported by the pilot for the flight on April 14. Lines representing a dry adiabat and the NACA standard atmospheric pressure-temperature relationship are included for comparison with the surveys (temperature range of the standard atmosphere was lower than the range of temperatures on March 27 shown in fig. 2(a)).

The surveys of pressure and temperature showed appreciable ranges of altitude that were isothermal or in which a temperature inversion occurred, both conditions favorable to the temperature method of airspeed calibration. There were, however, erratic differences of as much as 4° C between the two surveys of each flight; and, in fact, differences of 4° C were apparent even in a given survey of altitudes at the time when the airplane stopped climbing momentarily (for example, pressure altitude near 40,000 feet in second survey shown in fig. 2(a)). The spread of temperature values at a particular pressure level was probably an effect of the variation of temperature with time and with the horizontal distance covered in the surveys. As mentioned previously, both thermometers indicated the same temperature to within 0.3° C.

Airspeed calibration.- The effect of these large differences in temperature on the calibration of the airspeed installation by the temperature method is shown in figure 3 where the ratio of the difference between measured static pressure p' and free-stream static pressure p to the measured impact pressure q_c' is plotted against the indicated Mach number M'. The airspeed calibration was evaluated by using the average of the two surveys for a given flight only in the range of pressure altitudes for which the temperature of the atmosphere was isothermal or for which a temperature inversion was indicated by the surveys. Even with this selection of data, the scatter in the values of static-pressure error is too large for an acceptable calibration of the airspeed installation. The maximum scatter of static-pressure error is about $0.12\ q_c'$ and, for an isothermal atmosphere, corresponds to a temperature scatter of about 7° C, which is greater than the difference between the two surveys of any flight. The average of the two surveys in a flight may not represent the atmosphere through which the dive of that flight was made.

Since clear-air turbulence was encountered in the flights, consideration was given to the possibility that the temperature scatter was caused by the noted turbulence. Therefore, a plot of the variations of static-pressure error with indicated Mach number was made by using only the data obtained in the altitude ranges with temperature inversion or isothermal conditions for which no appreciable turbulence was encountered. The results shown in figure 4 indicate a reduction in the scatter, but the remaining scatter (about $0.05\ q_c'$) is still unsatisfactory.

Unpublished results of a calibration by the radar method of a similar airspeed installation on another airplane of the same design as used in the present tests are shown in figure 3 for comparison with the evaluation by the temperature method. The dotted lines in figure 3 indicate the scatter of the data obtained for the radar method. The average value of the static-pressure error determined by the temperature method is about 1 to 2 percent of the measured impact pressure q_c' above the curve representing the average of the data for the calibration by the radar method. The scatter in values of static-pressure error is apparently large enough to mask the relatively large variation of the static-pressure error with Mach number.

CONCLUDING REMARKS

An investigation was made to determine whether the temperature and pressure conditions in the lower stratosphere would meet the requirements of the temperature method for accurate calibration of airspeed installations. Although the tests were conducted on only four separate days within a three-week period, the results indicate that the temperature method does not appear to be very promising for airspeed calibration in the lower stratosphere. Some improvement in the results obtained may perhaps be realized if an airplane having a better climb performance (describing a helix of smaller radius in the surveys) were used.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., December 16, 1953.

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2. Lina, Lindsay J., and Ricker, Harry H., Jr.: Measurements of Temperature Variations in the Atmosphere Near the Tropopause With Reference to Airspeed Calibration by the Temperature Method. NACA TN 2807, 1952.

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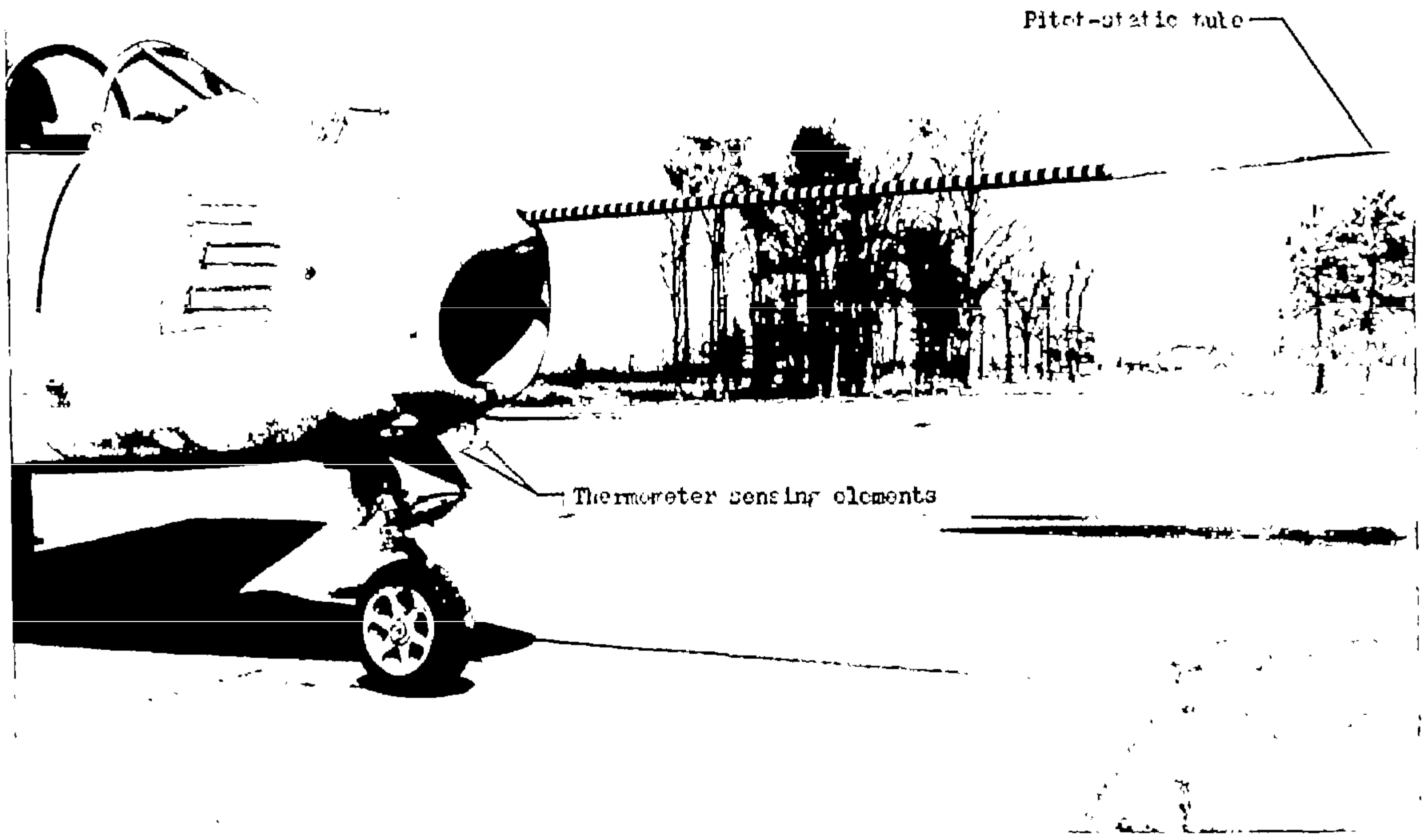

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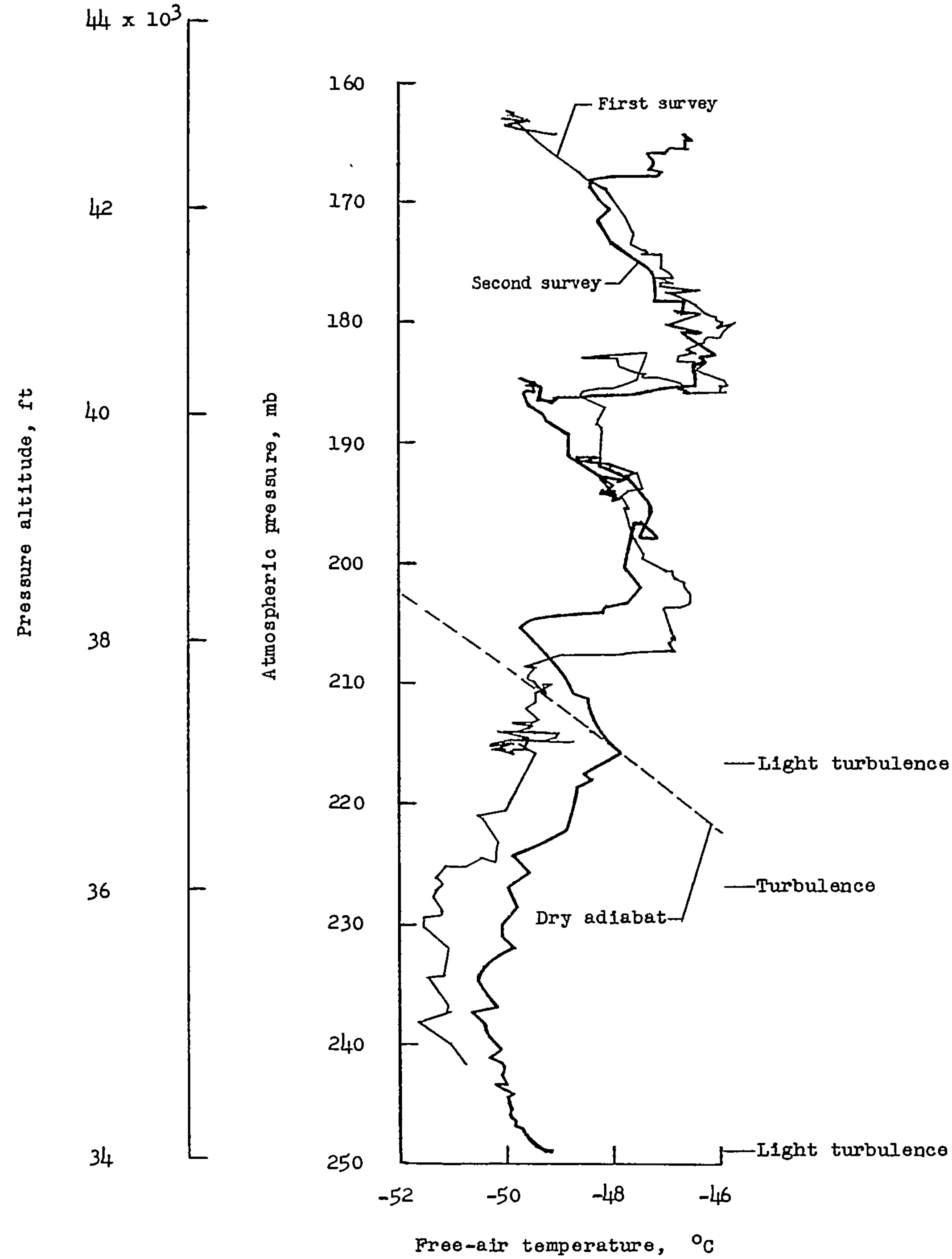
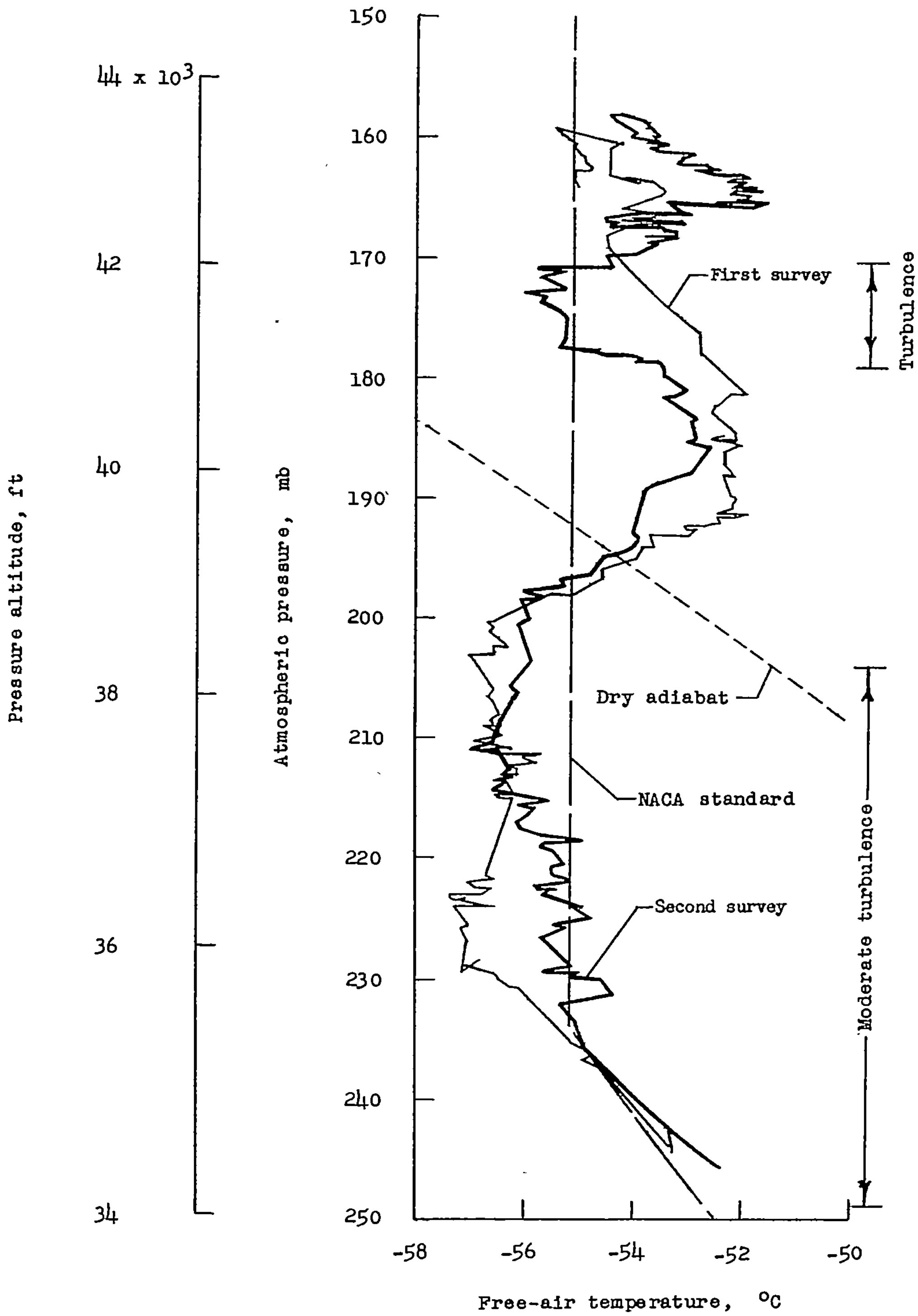
Figure 1.- Nose boom, pitot-static tube, and thermometer sensing elements installed on airplane.



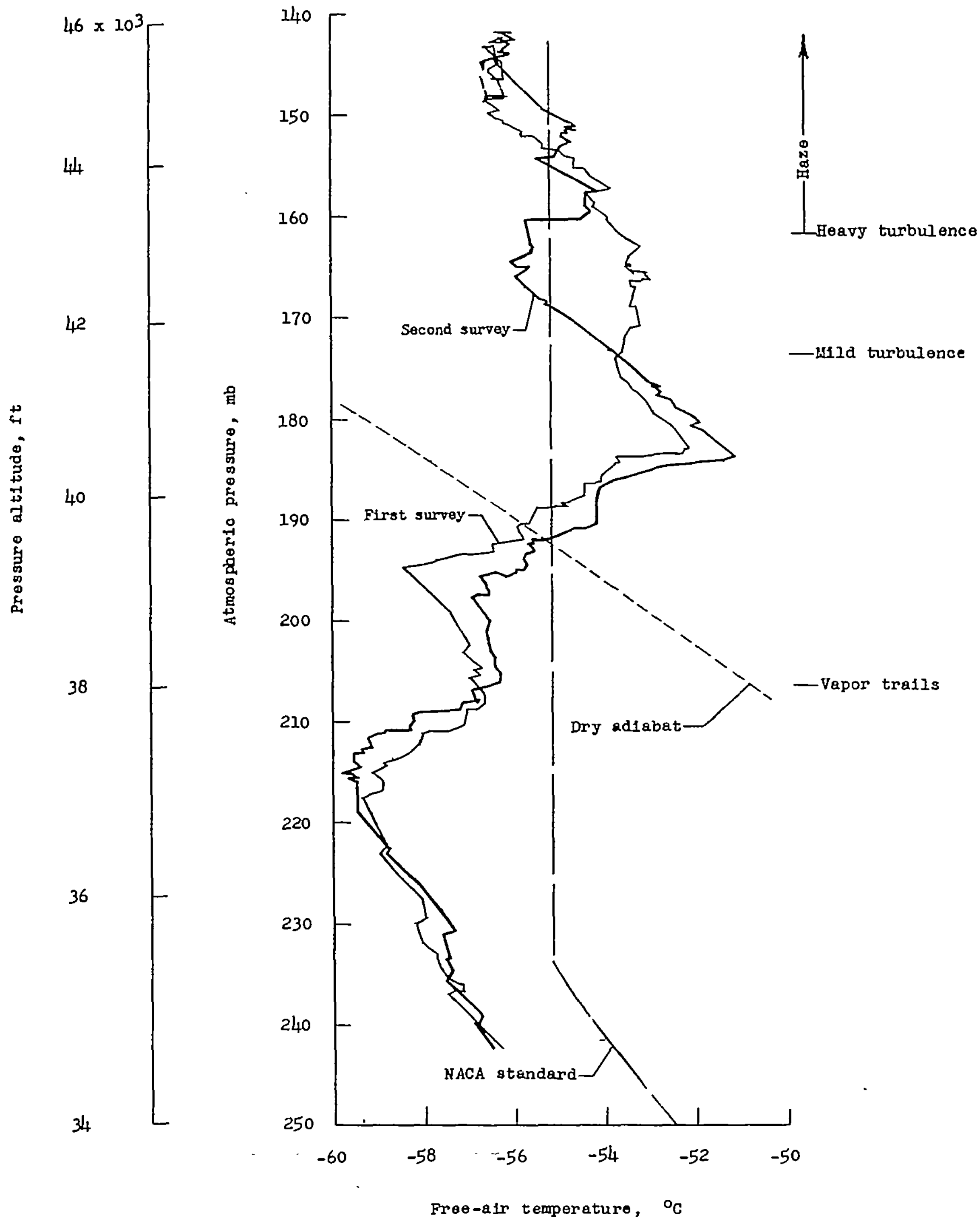
(a) March 27 from about 0945 EST to 1002 EST.

Figure 2.- Variation of free-air temperature with atmospheric pressure. Surveys were made in spiral climbing flight at a Mach number of about 0.8.



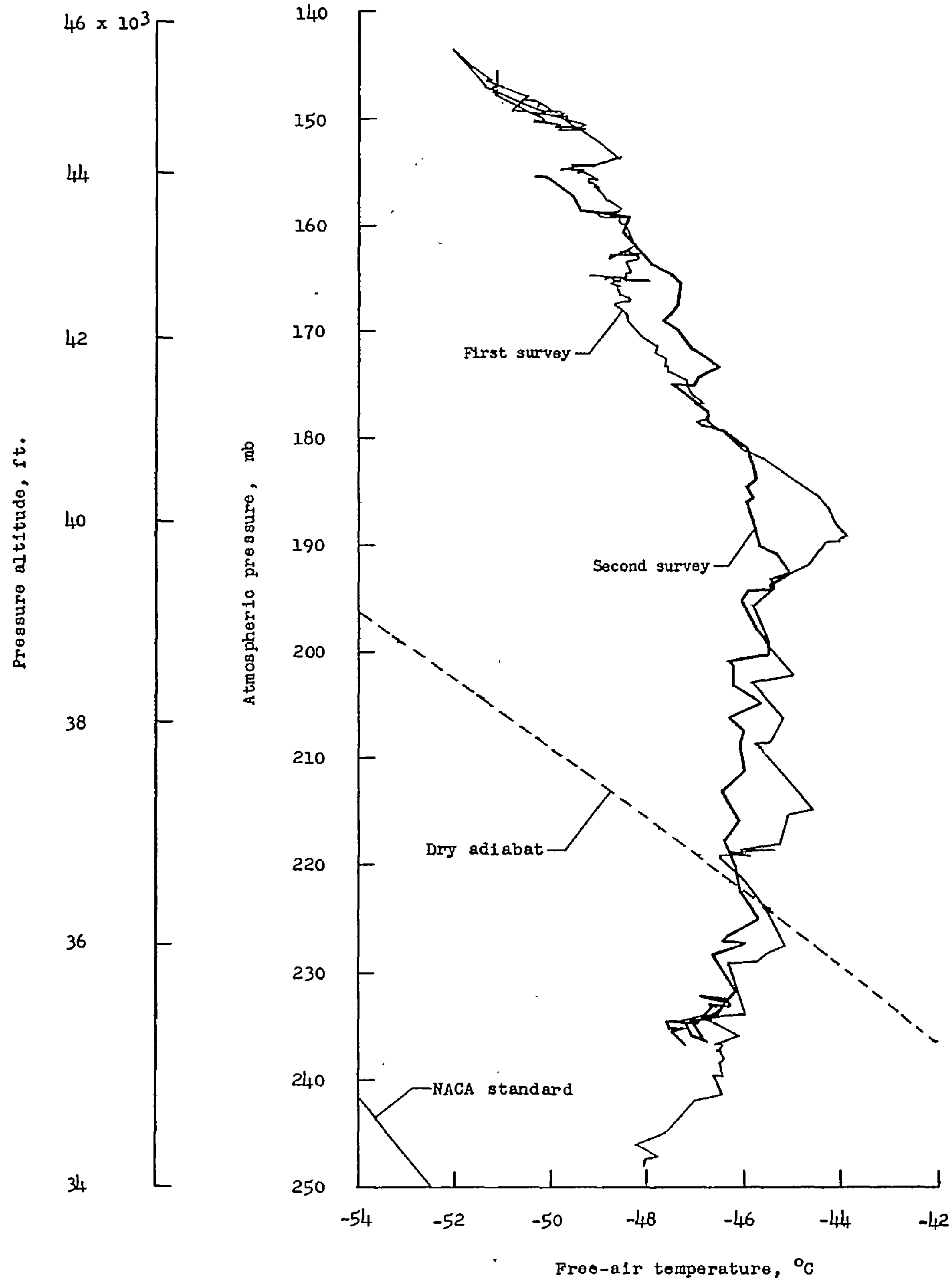
(b) March 30 from about 1235 EST to 1252 EST.

Figure 2.- Continued.



(c) April 8 from about 1405 EST to 1422 EST.

Figure 2.- Continued.



(d) April 14 from about 1100 EST to 1117 EST.

Figure 2.- Concluded.

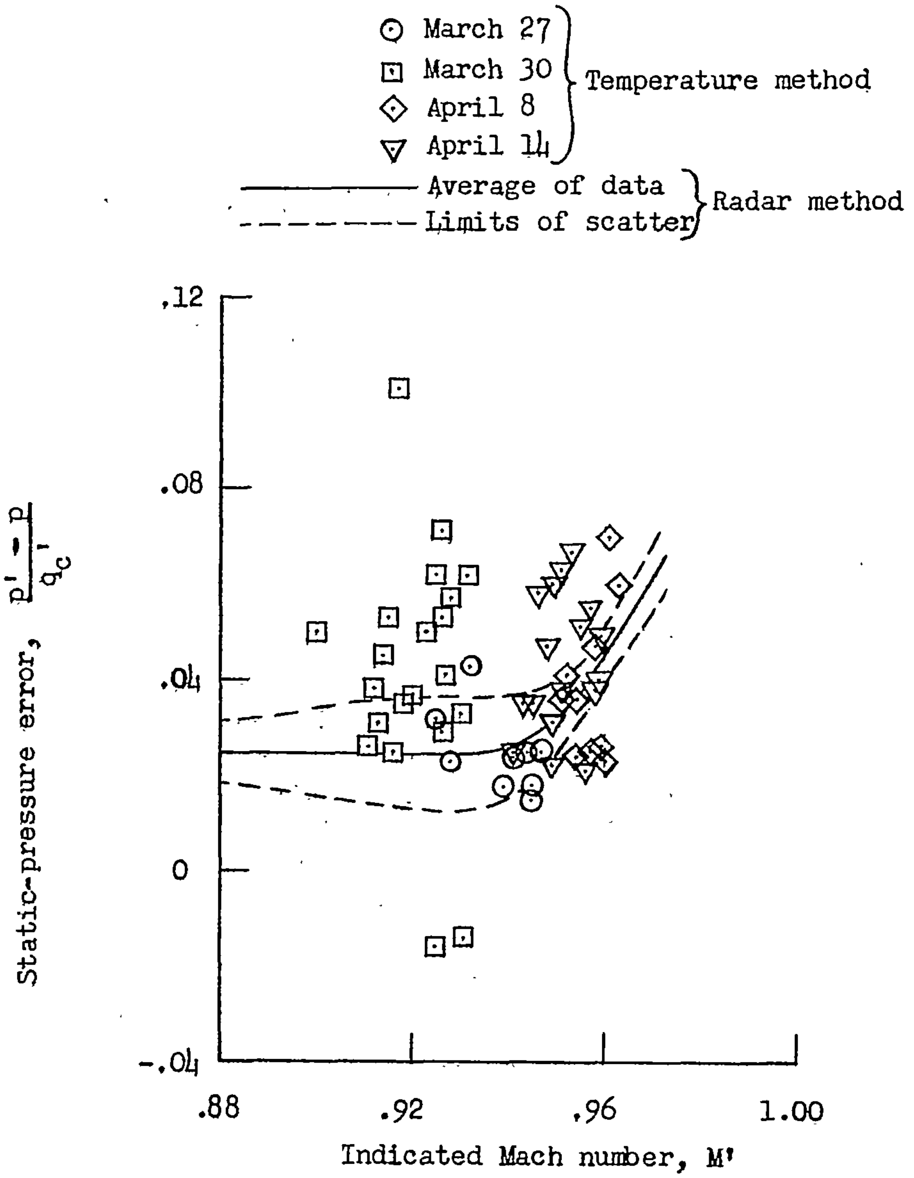


Figure 3.- Error in static pressure determined by evaluation of surveys and dives.

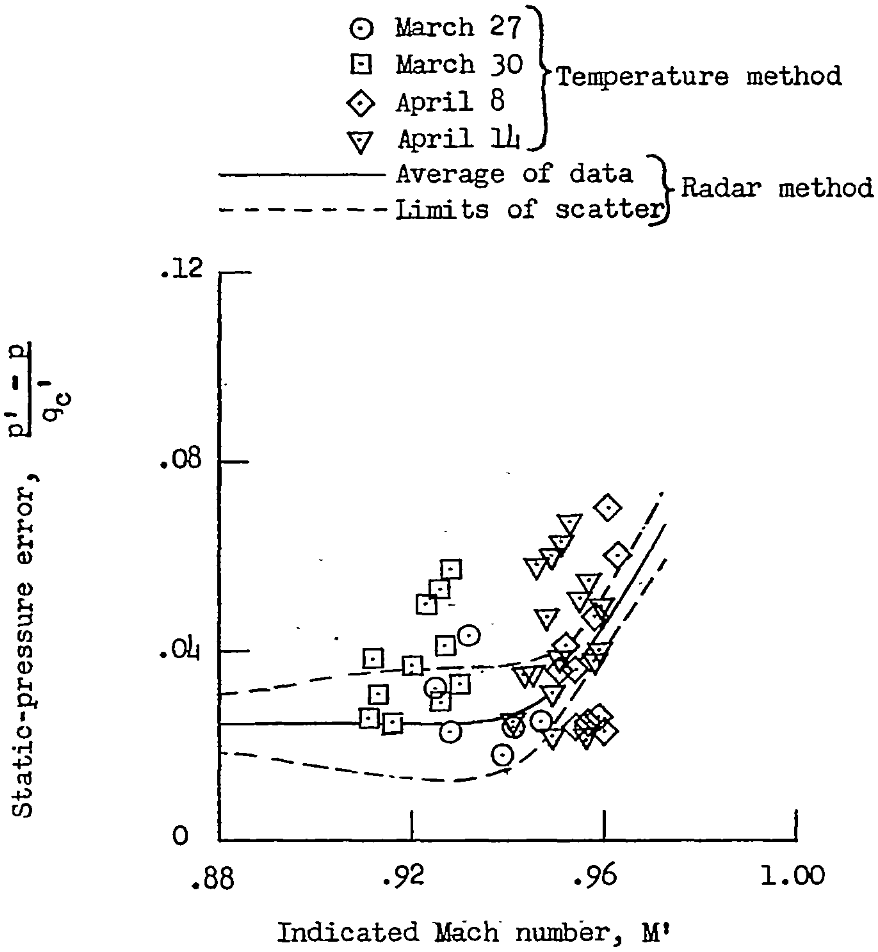


Figure 4.- Error in static pressure determined by evaluation of surveys and dives, excluding data obtained in turbulent air.

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